X-692-71-316
PREPRINT

NASA TM X-65664

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AUGUST 1971

GSFC

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A NOTE ON LARGE VELOCITY DISCONTINUITIES IN THE SOLAR WIND

by

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Recently, Ivanov (1970) showed that an interesting new kind of discontinuity, which he called "rotational," might exist in an anisotropic medium, and he stated that 10 of the 11 discontinuities in Burlaga (1969) must be of this new type. We shall show that 5 of those discontinuities are not "rotational." We shall also use the recent work by Hudson (1970, 1971) to show that most of the discontinuities in Burlaga (1969) are probably not rotational discontinuities in the more familiar sense of the word.

Ivanov's "rotational" discontinuities

The discontinuity predicted by Ivanov has the following characteristics: 1) there is a mass flux through the surface, 2) the density is the same on both sides of the surface, 3) there is a component of magnetic field $\underset{\sim}{B}$ normal to the surface, and 4) the components of $\underset{\sim}{B}$ parallel to the surface on sides 1 and 2 are themselves colinear, but different in magnitude. The fourth characteristic implies that the normal to this type of discontinuity is given by

$$\hat{n}_R = \frac{(\underset{\sim}{B}_1 \times \underset{\sim}{B}_2) \times (\underset{\sim}{B}_1 - \underset{\sim}{B}_2)}{|(\underset{\sim}{B}_1 \times \underset{\sim}{B}_2) \times (\underset{\sim}{B}_1 - \underset{\sim}{B}_2)|} \tag{1}$$

On the other hand, if the discontinuity is tangential,

$$\hat{n}_T = \frac{\underset{\sim}{B}_1 \times \underset{\sim}{B}_2}{|\underset{\sim}{B}_1 \times \underset{\sim}{B}_2|} \tag{2}$$

Burlaga and Ness (1970) showed how one can use magnetic field measurements from 2 spacecraft and the solar wind speed to determine a vector $\underset{\sim}{P}$ which is parallel to the surface of a given discontinuity. Clearly, if a discontinuity is tangential, $\hat{n}_T \; \underset{\sim}{P} = 0$; if it is "rotational", $\hat{n}_R . \underset{\sim}{P} = 0$. This test can be applied to 3 of the discontinuities in Burlaga (1969):

<u>Nov. 17, 1967</u> (H). This discontinuity, labeled(H)in Burlaga (1969), was seen at 0553.0 ± .5 UT by the magnetometer on Explorer 34 and at 0542.1 ± 1.0 UT by Explorer 33 (These times are based on the magnetic field data; the times in Burlaga (1969) are based on plasma measurements taken at 3 min. intervals). The spacecraft positions in solar ecliptic coordinates were (9.4, -21.8, 5.6) R_E and (9.6, 57.8, -27.5) R_E, respectively. Following the method in Burlaga and Ness (1970) one finds $\underset{\sim}{P}$ = (-.47, .82, -.34). From (1) and (2) one finds $\hat{n}_R$ = (-.15, . 71, -.68) and $\hat{n}_T$ = (.35, .71, .63). Thus, $\hat{n}_R . \underset{\sim}{P} = .88$ and $\hat{n}_T . \underset{\sim}{P} = .20 \pm .25$. If the actual orientation were that of a "rotational" discontinuity, $\hat{n}_R . \underset{\sim}{P}$ should be zero. Clearly, this is not the case; the discontinuity is not "rotational." On the other hand, the orientation is consistent with that for a tangential discontinuity.

Oct. 30, 1967 (E) this passed Explorer 35 at 1940.0 ± .3 UT and Explorer 34 at 1956.7 ± .5 UT. The spacecraft positions were (45.8, -32.6, 2.4) R_E and (16.5, -19.5, 5.1) R_E, respectively. These data give $\underset{\sim}{P}$ = (.96, .27, .06). Eq. (1) gives $\hat{n}_R$ = (-.45, -.29, .84), while (2) predicts $\hat{n}_T$ = (-.08, .97, .26). Thus $\hat{n}_R \cdot \underset{\sim}{P} = -.46$ and $\hat{n}_T \cdot \underset{\sim}{P} = .20 \pm .20$. Again, the result is distinctly different from that predicted for a "rotational" discontinuity, but it is consistent with that predicted for a tangential discontinuity.

Sept. 29, 1967 (D). This passed Explorer 33, 34 and 35 (located at (19.7, 48.3, 8.1) R_E, (30.2, -10.3, 1.4) R_E, and (33.5, -48.9, 5.5) R_E respectively) at 1957.0 ± .7 UT, 2002.2 ± .2 UT and 2003.5 ± .5 UT, respectively. This gives $\underset{\sim}{P}_1$ = (.50, -.86, -.02) from Explorers 35 and 33, and $\underset{\sim}{P}_2$ = (.53, -.84, .09) from Explorer 35 and 34. Thus, $\underset{\sim}{P}_1 \cdot \hat{n}_T = -.21 \pm .25$ and $\underset{\sim}{P}_2 \cdot \hat{n}_T = -.18 \pm .25$ consistent with the value required for a tangential discontinuity.

Unfortunately, we have no simultaneous interplanetary magnetic field measurements for the other discontinuities in Burlaga (1969). But one can show in another way that 2 other discontinuities are probably tangential:

Aug. 4, 1967 (A). As shown in Figure 5 in Burlaga (1969), there was a current sheet associated with the discontinuity which was thick enough to be analyzed. Using the method described in Siscoe et al. (1968), Burlaga (1969) found that $\underset{\sim}{B}$ rotated in a plane whose normal was $\theta_n = 54^\circ$, $\varphi_n = 22^\circ$, in good agreement with the value $\theta_N = 55^\circ$, $\varphi_N = 10^\circ$ predicted by (2). (θ and φ should be interchanged at the top of page 82 in Burlaga (1969)). For a "rotational" discontinuity, $\theta_N = -22^{\circ}$ and $\varphi_n = 67^{\circ}$, which is inconsistent with the value determined from the current sheet. Burlaga found no component of $\underset{\sim}{B}$ normal to the current sheet. This is consistent with a tangential discontinuity, but it is not consistent with a rotational discontinuity.

Sept. 20, 1967 (B). Here too, there was a thick current sheet, As discussed in Burlaga (1969), the normal obtained from the current sheet is $\theta_n = -56^{\circ}$, $\varphi_n = 60^{\circ}$. This is marginally consistent with the v alue obtained from (2), $\theta_n = -36^{\circ}$, $\varphi_n = 33^{\circ}$; it is not consistent with that predicted by (1), $\theta_n = -54^{\circ}$, $\varphi_n = 203^{\circ}$. Ivanov's table shows that the observed V_2 does not agree with V^* predicted for a "rotational"discontinuity. There is possibly a small component of $\underset{\sim}{B}$ normal to the rotation fan $(1.5 \pm .6)\ \gamma$, however.

In summary, at least five of the discontinuities in Burlaga (1969) (A,B,D,E,H) are probably not "rotational" discontinuities with $\underset{\sim}{B}_1$, $\underset{\sim}{B}_2$, and $\hat{n}$ coplanar. At least four of them do have the orientations predicted for tangential discontinuities.

Rotational Discontinuities

Let us now consider whether the discontinuities in Burlaga (1969) are rotational discontinuities in the familiar sense of the word. The theory of such discontinuities in an anisotropic medium is given by Hudson (1970, 1971). Hudson (1971) shows that both density, n, and B may change across and RD in an anisotropic medium, but the changes should have opposite signs (except in rare solar wind conditions). Discontinuities

F and K in Burlaga (1969) show significant changes in n and B with the <u>same</u> sign. Discontinuities A and J show changes in n and B which are possibly real which also have the same sign. Hudson (1971) shows that the density change $n_2 n_1$ is ≤ 2.5 and is usually close to 1; this suggests that (B) is also not rotational. Finally, (G) can be excluded because it doesn't satisfy the necessary condition relating changes in $\underset{\sim}{V}$ and $\underset{\sim}{B}$ (Hudson, 1970).

In summary discontinuities A, B, F, G, I, and K are probably not rotational discontinuities.

Conclusions

Additional data were examined which show Ivanov's conclusion observe that 10 of the 11 discontinuities in Burlaga (1969) are 'rotational" to be incorrect. None of the 5 discontinuities for which we were able to compute the normal had the orientation predicted by Ivanov. It was also shown that 6 of those discontinuities are probably not rotational in the sense of Hudson. While we cannot definitely rule out the possibility that some of the discontinuities in Burlaga (1969) are rotational, it is clear that at least several of them are probably tangential. Thus, Burlaga's interpretation that there are tangential discontinuities in the solar wind with large shears is substantiated.

The identification of discontinuities of the type predicted by Hudson and Ivanov would be of great interest. If they do exist they are probably characterized by $\Delta U < 60$ km/sec. Complete, high quality data from at least 2 spacecraft will be needed for conclusive identification.

Acknowledgment

The author wishes to thank Drs. Ivanov and Hudson for their letters concerning the matters discussed in this paper.

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